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LIQUEFIED PETROLEUM GAS (LPG) AND NATURAL GAS (NG) - FIRE PREVENTION ISSUES

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Review article

Abstract: In this paper it is proposed to identify Codes of Practice/Standards which are currently and widely used by enforcing authorities to ensure LPG/NG installations are installed and commissioned to a satisfactory relevant standard. It is proposed to highlight some key aspects of the codes for comparison purposes with a view to assisting enforcing authorities to identify and specify suitable precautions in relation to LPG/NG installations.

Key words: Fire prevention, Liquefied Petroleum Gas, Natural Gas.

Introduction

In this presentation it is proposed to look at a number of codes/standards in relation to LPG and Natural Gas and give an overview of their requirements in relation to storage and fire prevention requirements. There are numerous codes and standards covering all aspects of gas storage/ installations and it would be impossible in the time allocated to go into detail in relation to any one of these. It is, however, proposed to highlight some commonly used codes and standards and outline some of the requirements contained in them. This will give a "flavour" of their content. However in order to use such codes or standards a complete copy of the standard or code is required. I have attached a reference to the codes cited in the presentation.

Materials and methods

Liquefied Petroleum Gas - LPG

Liquefied Petroleum Gases - LPG's - are usually produced during the refining processes of crude oil but also occur as free gases in some gas fields associated with, for example, North Sea Oil.

The commercial grades are not chemically pure propane or butane or mixtures of the two, but may also contain traces of ethane, ethylene, propylene, isobutene or butylene which can cause slight variations in property value.

The principal properties (typical) of LPG (Propane and Butane) are outlined below.

Typical properties* of commercial butane and propane at standard temperature and pressure conditions at 15°C and 1013 - 1015 mbar:

Tab. 1 Physical properties

Physical Properties	Commercial Butane C_4H_{10}	Commercial Propane C_3H_8
Freezing Point at Atmospheric Pressure	-140°C	-186°C
Boiling Point at Atmospheric Pressure	-2°C	-42°C
Specific Gravity of Gas (Air = 1)	2.0	1.5
Specific Gravity of Liquid (Water = 1)	0.575	0.512
Volume of Gas produced per Unit Volume of Liquid	233	274
Volumes of gas/air mixture at lower limit of flammability from 1 volume of liquid at 15.6°C and 1 015.9 mbar	12 900	12 450
Volume occupied per mass of Liquid	1743 litres/ tonne	1957 litres/ tonne
Volume of Air to burn Unit Volume of Gas	30	23
Volume of Oxygen to burn Unit Volume of Gas	6.25	4.8
Ignition Temperature	410-550°C	460-580°C
Maximum Flame Temperature	1996°C	1980°C
Lower limit of flammability, % v/v	1.8	2.2
Upper limit of flammability, % v/v	9.0	10.0
Calorific Value MJ/m^3	120	95

* All figures are approximate; the actual figure depends on the actual composition.

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The National Fire Protection Association NFPA Code 58 - Liquefied Petroleum Gas Code - applies to the storage, handling, transportation and use of LPG.

The code applies to:

- Containers, piping and associated equipment when delivering LPG to a building for use as a fuel

and also applies to:

- Highway transportation of LPG
- Marine terminals who receive LPG for delivery to distributors, etc.

The NFPA Code also has an Equivalency Clause where it states nothing in the code is intended to prevent the use of systems, methods or devices of equivalent or superior quality, strength, fire resistance, effectiveness, durability and safety over those prescribed by this code. Technical documentation shall be submitted to the authority having jurisdiction to determine equivalency.

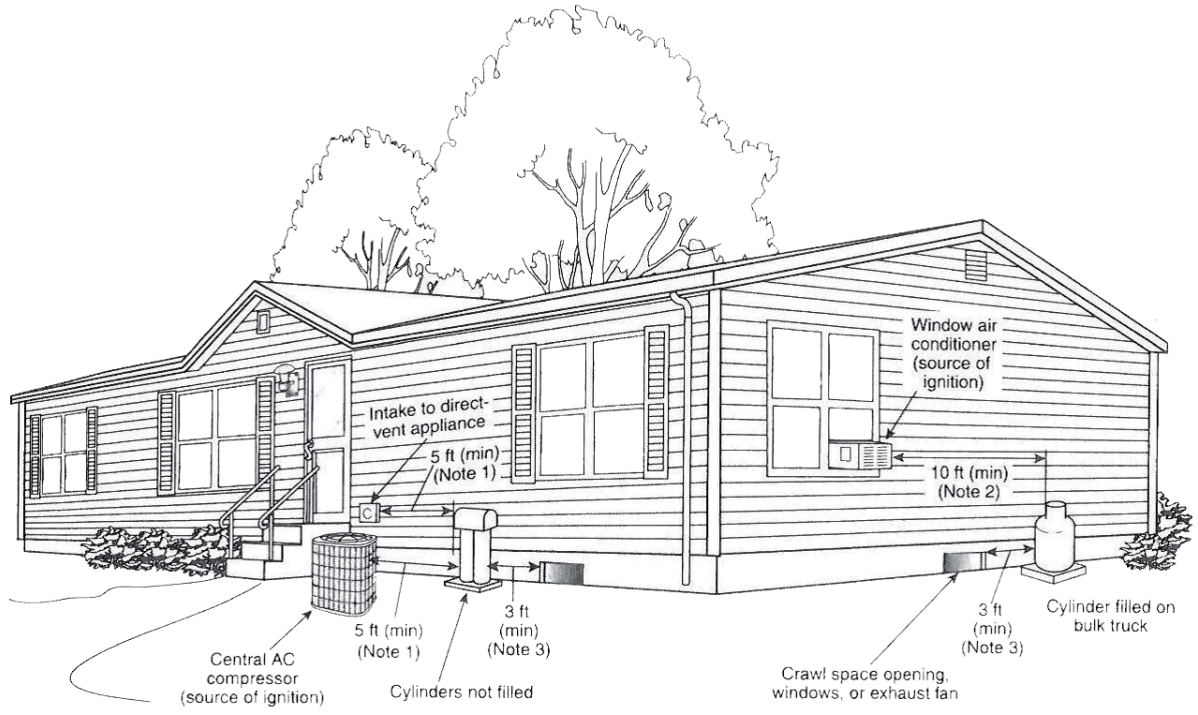
This code is very comprehensive and contains a lot of technical detail. However, I will outline the guidance on the spacing of containers. I will do this by referring to illustrative figures from the code. In order to get full clarification on the contents you are advised to refer to the code.

- I.S. 3216 Code of Practice - Bulk Storage of Liquefied Petroleum Gas

This standard published by the National Standards Authority of Ireland deals with the storage of LPG under pressure at ambient temperatures in fixed and skid mounted vessels larger than 150 litres. I will look at a few examples from this standard.

LPG vessels sited above ground should be located in the open air in a well-ventilated position in accordance with the separation distances given in Tab. 2.

To determine the separation distances for any group of tanks, the capacity of the largest tank in the group shall not exceed the value given in the relevant row in column 1 of Tab. 2 and the total capacity of all the tanks in the group shall not exceed the value given in column 3 in the same row of Table 2. The number of above ground LPG vessels in one group shall not exceed 3 (see 4.1.13).



For SI units, 1 ft = 0.3048 m

Note 1: 5 ft minimum from relief valve in any direction away from any exterior source of ignition, openings into direct-vent appliances, or mechanical ventilation air intakes.

Note 2: If the cylinder is filled on site from a bulk truck, the filling connection and vent valve must be at least 10 ft from any exterior source of ignition, openings into direct-vent appliances, or mechanical ventilation air intakes. Refer to 6.3.9.

Note 3: Refer to 6.3.8.

Fig. 1 Cylinders (NFPA 58)

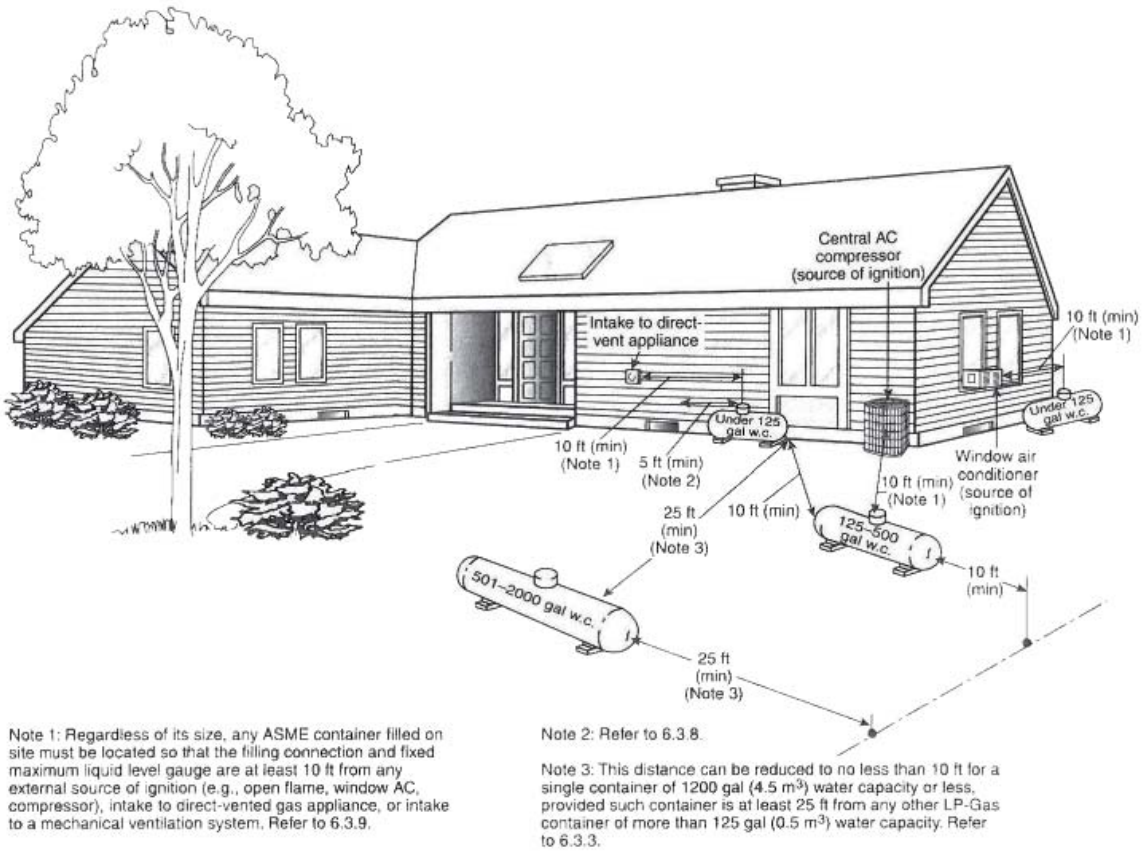


Fig. 2 Aboveground ASME Containers (NFPA 58)

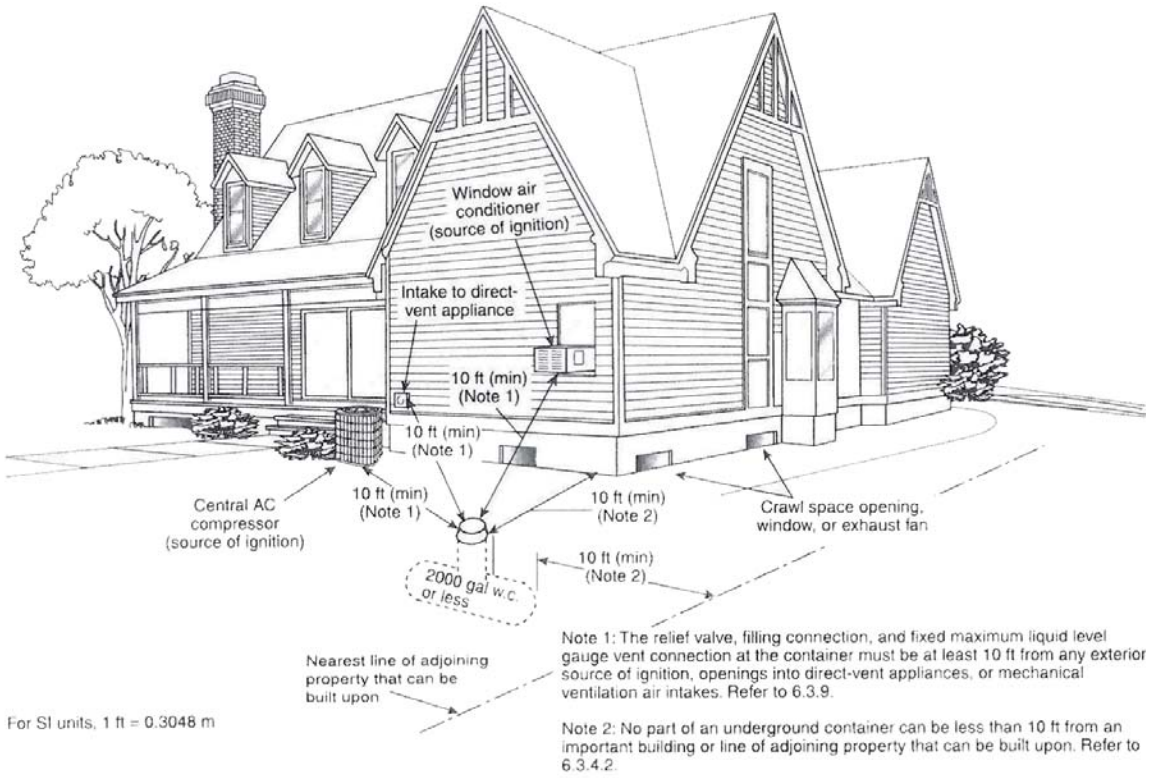


Fig. 3 Underground ASME Containers (NFPA 58)

For separation distances from buildings, in the case of vessels up to 2 500 litre capacity, the separation distances in Tab. 2 column (b) may be used, provided the construction of the external wall of the building, the area shown shaded in Fig. 1, is non-combustible and is of construction having a minimum period of fire resistance of 60 minutes. The vessel location should be selected to give maximum protection against accidental damage and to take maximum advantage of natural ventilation. Underground or mounded vessels shall be located so that the manhole and pressure relief valves are in a well-ventilated position in accordance with the separation distances given in Tab. 2.

- Small Bulk Vessels adjacent to a Building

View Fig. 4 Small bulk vessel adjacent to a building.

- Water Supplies

At all installations there should be an adequate supply of water for fire protection use in an emergency. To provide adequate protection for a vessel threatened by fire an application rate of 10 l/m^2/min over the whole surface of the vessel for at least 60 minutes is required. The capacity of the supply may need to be increased where no alternative water supplies are available near the premises.

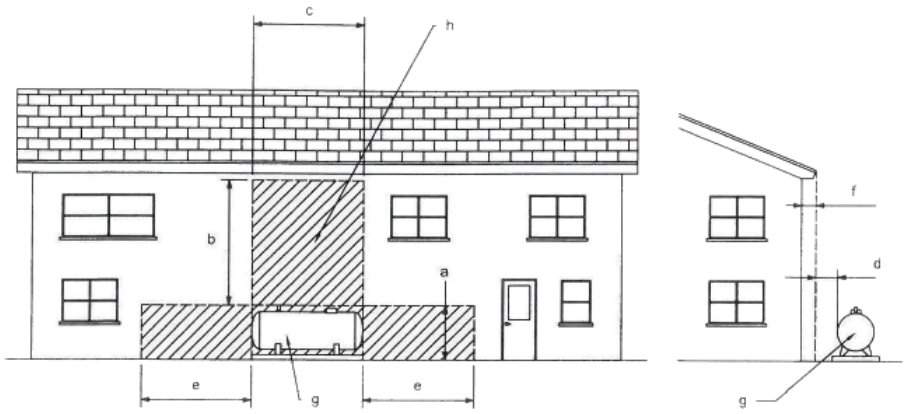
Tab. 2 Minimum separation distances (I.S. 3216:2010)

Nominal capacity of any single vessel in group		Maximum capacity of all vessels in a group	Above ground vessels			Buried or mounded tanks			
Water capacity (litres)	LPG capacity (tonnes)	LPG capacity (tonnes)	From buildings, boundary, property line or fixed source of ignition		(c) Between vessels in a group (m)	From buildings etc. to			
			(a) Without fire wall (m)	(b) With fire wall (m)		Valve assembly cover		(f) Vessel (m)	(g) Between vessels (m)
						Without gas dispersion wall (m) (d)	(e) With gas dispersion wall (m)		
150 to 500	0,05 to 0,25	0,8	2,5	0,3[a)]	0,3	2,5[c)]	1,5[c)]	1	0,3[b)]
Up to 2500	Up to 1,1	3,5	3	1,5[a)]	1	3[c)]	1,5[c)]	1	1[b)]
Up to 9000	Up to 4	12,5	7,5	4	1	3[c)]	1,5[c)]	1	1[b)]
Up to 135000	Up to 60	200	15	7,5	1,5	7,5[c)]	7,5[c)]	3	1[b)]
Up to 337500	Up to 150	460	22,5	11	¼ of the sum of the diameter of 2 adjacent tanks	11[c)]	11[c)]	3	1[b)]
>337500	>150	1000	30	15	¼ of the sum of the diameter of 2 adjacent tanks	15[c)]	15[c)]	3	1[b)]

[a)] For vessels up to 500 litres capacity, the fire wall needs to be no higher than the top of the vessel and may form part of the site boundary. The fire wall for a tank up to 2500 litres water capacity may form part of a building wall in accordance with Figure 1. Where part of the building is used as a firewall, the wall including any overhang, against which the LPG is stored should be 60 minutes fire-resisting construction and imperforate.

[b)] For below ground, mounded storage the spacing between adjacent vessels shall be determined by the site conditions and requirements for safety installations, removal of such vessels as well as their inspection testing and maintenance.

[c)] See Annex C



Key:

a Height of top of Pressure Relief Valve (PRV)
b 9 m
c Length of vessel
d 0,3 m for vessels up to 500 litres
1,5 m for vessels > 500 litres to 2 500 litres
e 2,5 m for vessels up to 500 litres
3,0 m for vessels > 500 litres to 2 500 litres
f Roof overhang
g LPG vessel
h 60 minutes minimum fire resistance and imperforate

Fig. 4 Small bulk vessel adjacent to a building

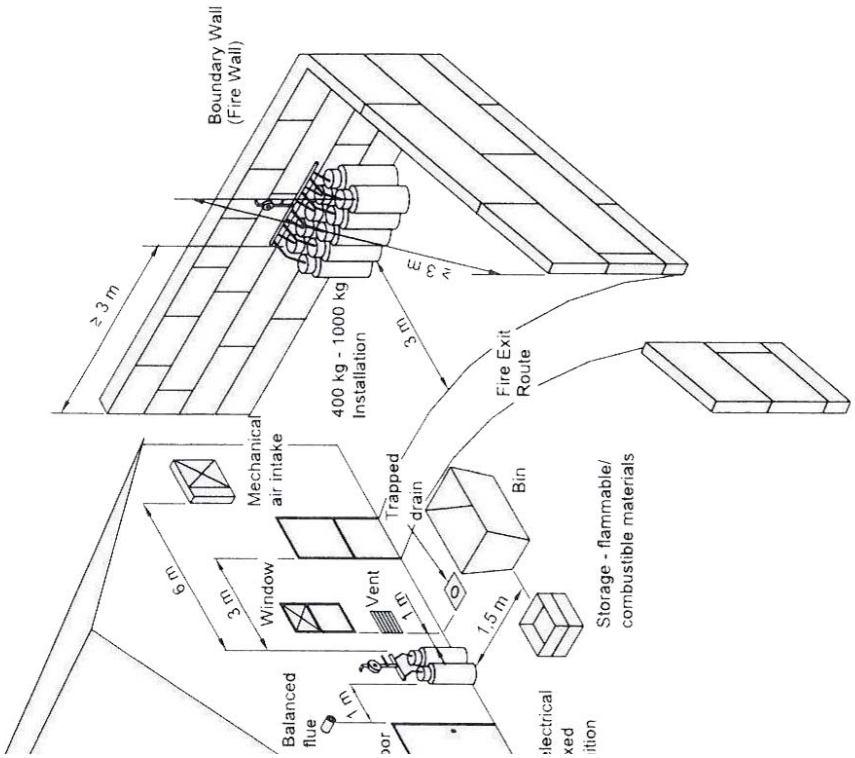


Fig. 5 Overview of minimum horizontal separation distances (I.S. 820:2010)

If water is supplied via a recirculating-system the storage reservoir should hold 30 minutes supply without recirculation. Special consideration should be given to the possibility that there could be a loss of power on the site and the consequences this would have for the fire fighting arrangements provided.

Tab. 3 Summary of fire precaution requirements (I.S. 3216:2010)

Installations capacity (litres)	Fire precautions	Clause No.
150 - 56 250 Domestic[1]	Water supply for fire brigade use < 100 m away	13.2.1 13.1.5 13.4 13.5.1
150 to 2500 Non domestic	Water supply for fire brigade use < 100 m away and 1x hose reel not less than 19 mm nominal before	13.2.1, 13.1.5, 13.4
	1x hose reel not less than 19 mm nominal before or 2x 9 litre water extinguishers	13.9.2
	2x 9 kg dry powder extinguishers	13.9.3
>2500 to <56250 (1,1 te to 25 te) Non-domestic	Water supply for fire brigade use	13.2.1, 13.1.5, 13.5.1
	1x hose reel not less than 19 mm nominal before	13.9.2
	2x 9 kg dry powder extinguishers	13.9.3
Liquid off-take >15 750 vessel capacity (7 te)	Water supply	13.2.1, 13.1.5
	Means of supplying cooling water to vessels	13.5.2
	Hose reel not less than 19 mm nominal before	13.9.2
	2x 9 kg dry powder extinguishers	13.9.3
56 250 to <112 500 (25 te to 50 te)	Water supply	13.2.1, 13.1.5
	Fixed and/or portable monitors	13.6
	Hose reel not less than 19 mm nominal before	13.9.2
	2x 9 kg dry powder extinguishers	13.9.3
≥ 112500 (50 te)	Water supply	13.2.1, 13.1.5
	Automatic fixed sprays	13.7
	Hose reel not less than 19 mm nominal before	13.9.2
	2x 9 kg dry powder extinguishers	13.9.3
Cylinder filling	Water supply	13.2.1, 13.1.5
	Automatic fixed sprays	13.7
	Hose reel not less than 19 mm nominal before	13.9.2
	2x 9 kg dry powder extinguishers	13.9.3
Road tanker filling/deliveries more than twice per week	Water supply	13.2.1, 13.1.5
	Additional fire protection	13.8.3
	Hose reel not less than 19 mm nominal before	13.9.2
	2x 9 kg dry powder extinguishers	13.9.3
[1] "Domestic" includes distribution systems.		

On-site hydrants and fixed drench systems shall be designed so that the control of water flow can be achieved from a safe position. Connections for fire brigade use should be provided on the water supply to fixed drench systems as required. These shall be located in a safe place and should be agreed with the fire authority. There should be adequate drainage to deal with water used for fire fighting and control purposes.

- I.S. 820 - Non-Domestic Gas Installations

I.S. 820 specifies the requirements for Natural Gas and LPG installations in commercial and public access buildings at maximum operating pressure not exceeding 5 bar.

This code gives guidance on the location of LPG (Propane) cylinders and I have included Fig. 5 for information.

In the UK the UKLPG produce Codes of Practice and guidance for the LPG industry. UKLPG is the trade organisation for the LPG industry and represents producers, distributors, equipment and service providers and vehicle converters. As the voice of LPG, UKLPG works at both National and European level actively seeking to raise awareness of the benefits of LPG. Codes are prepared by the UKLPG in consultation with the Health and Safety Executive (HSE).

The storage of bulk LPG storage is covered by UKLPG - Code of Practice 1 - Bulk LPG Storage of LPG at Fixed Installations

- Part 1 - Design, Installation and Operation of Vessels Located Above Ground

- Part 2 - Small Bulk Propane Installations for Domestic Purposes

The separation distance in Table 1 UKLPG Part 1 is similar to Table 1 in I.S. 3216 (UKLPG has minimum separation between tanks of 1m for tanks less than 0.25 tonnes, however I.S. 3216 permits a separation distance between tanks of 0.3m for tanks less than 0.25 tonnes).

For small bulk vessels adjacent to buildings see Fig. 6 below.

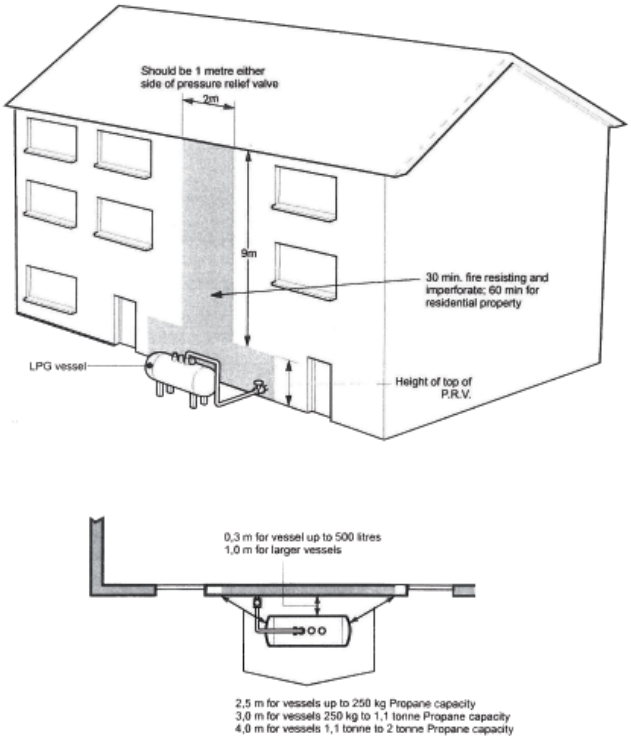


Fig. 6 Small bulk vessel adjacent to building (UKLPG Code of Practice 1 - Part 1)

Water supplies outlined in UKLPG are similar to I.S. 3216. The tables in UKLPG are Tab. 3 Fire Precautions and Tab. 9 Water Sources.

Natural Gas

Natural gas is defined as "a flammable gas consisting mainly of methane (CH_4) found in the earth's crust". There are no standards or conventions that specify a composition of natural gas. Natural gas consists principally of methane, but it also contains ethane and small amounts of propane, butane, and higher hydrocarbons. Also, natural gas can contain small amounts of nitrogen, carbon dioxide, hydrogen sulphide, and helium. Normally, natural gas contracts specify a heating calorific value.

The basic characteristics typical of natural gas are outlined below. These are representative values only and may vary according to the source of the gas (where necessary confirmation should be sought from the gas supply company).

The typical composition of natural gas is:

Methane	85.0	- 98.0 %
Ethane	0.3	- 8.2 %
Propane	0.01	- 2.9 %
Butane	0.003	- 0.6 %
Nitrogen	0.2	- 0.8 %
Carbon Dioxide	0.5	- 2.6 %

Fig. 7 Plus traces of pentanes and sulphur compounds

Tab. 4 Physical properties

Physical Properties		**Natural Gas**
Specific Gravity of Gas (air = 1.00)		0.56 - 0.65
Flammability Limits		
(% Gas in air):	Upper	15
	Lower	5

Natural gas has a calorific value of between 37-41 MJ/m^3. Bottled gas (LPG) can have a calorific value of two to over two and half times that of natural gas.

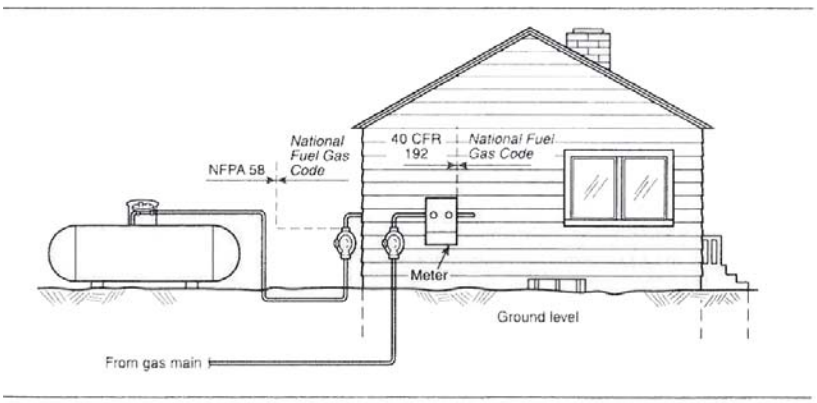


Fig. 8 Code Jurisdictions for Typical Propane Supply and Typical Natural Gas Supply

- NFPA - Codes

I include Fig. 8 which gives an overview of the jurisdiction of the NFPA Codes for natural and LPG gases (propane).

National Fuel Gas Code	-	NFPA 54 - Natural Gas and LPG
49 CFR 192	-	Federal Pipeline Regulations (Code of Federal Regulations)

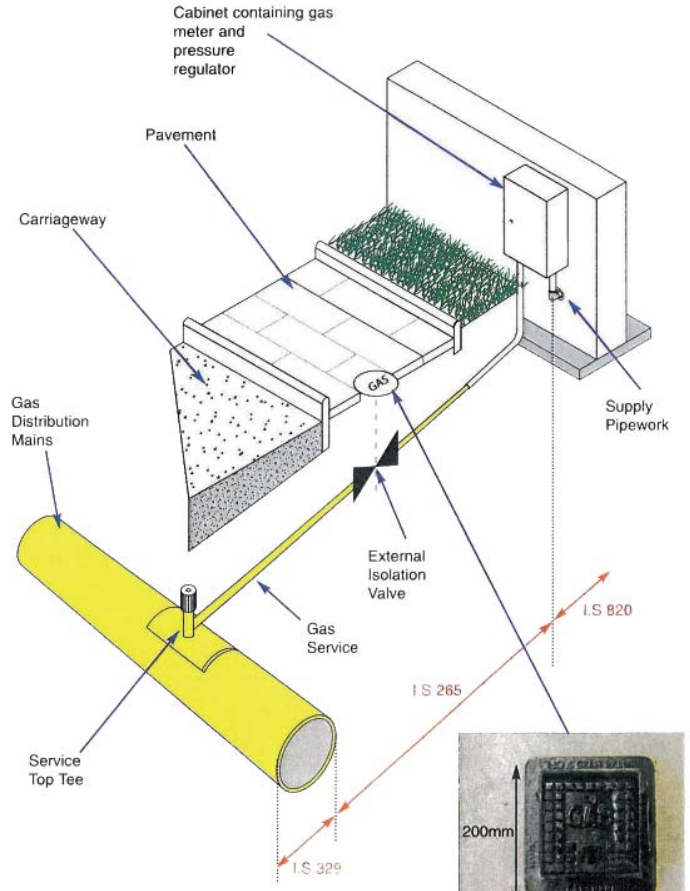
- Domestic Gas Installations

I.S. 813 is a code of practice for natural gas and LPG installation requirements downstream of the delivery point - includes guidance on location of LPG cylinders.

- Non Domestic Gas Installations

I.S. 820 specifies requirements for natural gas and LPG installations in commercial and public access buildings - includes guidance on location of LPG cylinders.

SITE WORK GUIDELINES



The external isolation valve and access cover should remain accessible at all times.

Note:

- Gas mains, services and meters transporting gas at pressures greater than 100mbar are not permitted inside the building line of occupied buildings
- PE piping is not permitted inside the building
- The service should travel as near perpendicular to the gas main as possible

Fig. 9 Natural Gas (Bord Gais)

Results

Certification of non-domestic gas installations

To ensure that the completed installation is fit for purpose the code requires a Declaration of Conformance. A Declaration of Conformance by a competent person gives the fire authority reassurance that the installation is installed and operating in a safe manner. This declaration is generally in 5 sections:

- Section I

This is for administration purposes - addresses for customers and installation and registration number.

- Section II - Design

The authorised person responsible for the design should complete the Declaration of Conformance attesting that the installation has been designed in accordance with the requirements of I.S. 820:2010 (or other nominated code/standard) and in accordance with the equipment and manufacturer's instructions. Any person who designs or carries out work on a gas installation should be a competent person.

- Section III - Construction

The Construction section should be completed by the person responsible for the construction of the gas installation downstream of point of delivery and in accordance with I.S. 820:2010.

During the construction of the pipework care should be taken to prevent the ingress of foreign matter (e.g. dirt, water, swarf, thread cutting oil etc.) into the pipework. Foreign matter which has entered the pipework should be removed.

Open ends of pipework and valve outlets should be sealed with an appropriate fitting.

Gas pipework should be identified in accordance with I.S. 820, refer to page 46 of this document - "Identification of Gas Pipework".

Pipework should be installed so that it does not impose excessive stress on devices or components incorporated into the pipework, e.g. meters, regulators, etc.

To carry out the test the contractor should isolate and blank their own work and only apply a test to the gas carrying pipework.

As stated within I.S. 820 - any person responsible for construction should be a competent person.

All tests should be performed in accordance with the test requirements detailed in this document and the current edition of I.S. 820:2010.

- Section IV - Integrity (Commissioning) Test (if required)

The Integrity Test (Commissioning Soundness Test) is required if the admission of gas does not immediately follow the initial construction test, or if appliances or components have been reconnected following the test. Then before proceeding with the admission of gas, the authorised person (not Bord Gais Networks) should conduct an Integrity Test.

The Integrity section should be completed by the person responsible for the Integrity/Commissioning Test of the gas installation downstream of point of delivery (in accordance with I.S. 820:2010). As stated within I.S. 820:2010, any person responsible for the Integrity Testing should be a competent person.

Any pipework not in use should be disconnected, purged and plugged, capped or sealed at each end. Where practicable, gas pipework not in use should be dismantled.

In performing the test the contractor should isolate and blank off their own work and only apply a test to the gas carrying pipework.

All tests should be performed in accordance with the test requirements as detailed below and within the current edition of I.S. 820:2010.

- Section V - Admission of Gas and Turn On

Purging and Admission of natural gas should be carried out by a competent person in accordance with I.S. 820.

Natural gas is admitted to the premise by the Gas Installer nominated by the Customer.

The admission of gas should be supervised by the authorised person responsible for carrying out the Integrity Commissioning Test.

Note: Competent person is defined in the standard as: "person having the ability, appropriate training, knowledge and experience to supervise or carry out the work being undertaken in a safe and proper manner".

In the U.K. the IGEM Institute of Gas Engineers and Managers are involved in writing and reviewing standards. IGEM Standards are drafted by expert Panels representing a cross-section of the relevant parts of the gas industry. Regulatory bodies such as HSE, Ofgem and Gas Safe Register contribute to the drafting process. The drafts are issued to the industry and other stakeholders for review and comment prior to publication and, thus, take into account the sometimes broad range of views on the content. The professional status of IGEM ensures its Standards reflect the best possible levels of safety, practice and quality.

IEGM/TD produce a series of technical standards (Transmission and Distribution) www.igem-org.uk/technicalstandards.

Conclusion

In this paper I have looked at a number of Codes/Standards as follows:

- National Fire Protection Association Codes
- Irish Standards
- United Kingdom Liquid Petroleum Gas Codes
- Institute of Gas Engineers and Managers
- Bord Gais

These codes are of assistance to fire safety officers in determining appropriate safety precautions at LPG/NG installations.

Precautions in relation to the storage and separation of LPG were examined from different codes for comparison purposes.

In conclusion, the content or focus of the various standards and codes ultimately address the same issues in relation to gas installations whether LPG or NG. Irrespective of the standard or code followed, the critical element appears to be the certification process, whereby some competent person must certify the installations conformance to a particular standard.

References

Bord Gais. Guidelines for Designers, Builders and Installers of Gas Installations. Available at: www.bordgais.ie

IGEM/TD. Institute of Gas Engineers and Managers. Transmission and Distribution. Available at: www.igem-org.uk/technicalstandards

I.S. 3216:2010. Code of Practice - Bulk Storage of Liquefied Petroleum Gas LPG (Edition 2).

I.S. 820:2010. Standard for Non-Domestic Gas Installations (Edition 2).

I.S. 813. Domestic Gas Installations.

NFPA 54. National Fuel Gas Code 2012 Edition.

NFPA 58. Liquefied Petroleum Gas Code 2011 Edition.

UKLPG, Code of Practice 3:2000. Recommendations for Prevention and Control of Fire Involving LPG. Incorporating Amendment 1 October 2006.

UKLPG, Code of Practice 1, Bulk LPG Storage at Fixed Installations, Part 1:2009 - Incorporating Amendment l May 2012.

UKLPG, Code of Practice 1, Bulk LPG Storage at Fixed Installations, Part 2:2012.